Navy Experimental Diving Unit
321 Bullfinch Rd.
Panama City, FL 32407-7015

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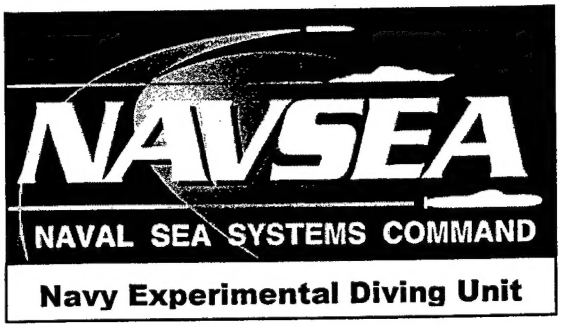
NEDU TR 02-11
September 02

THE EFFECTS OF WARM WATER DIVING ON PERFORMANCE:

NEUROPSYCHOLOGICAL FINDINGS USING THE AUTOMATED NEUROPSYCHOLOGICAL ASSESSMENT METRICS



Authors: Michael A. Lowe, Ph.D., LT, MSC, USNR
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THE EFFECTS OF WARM WATER DIVING ON PERFORMANCE: NEUROPSYCHOLOGICAL FINDINGS USING THE AUTOMATED NEUROPSYCHOLOGICAL ASSESSMENT METRICS (U)

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Twenty diver-subjects were exposed to various levels of water temperature to assess how warm water affects cognition. Because cognitive performance is essential to operational performance and safety, determining cognitive effects of warm water exposure was desirable. The Automated Neuropsychological Assessment Metrics (ANAM) software was used before and after each exposure to provide near real-time assessment of diver neuropsychological status. Decrements in sustained attention, vigilance, memory, pattern recognition and basic problem solving were noted and appear to be functions of warm water exposure.

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CONTENTS

Contents iii
Introduction 1
Methods 1
General 1
Experimental Design and Analysis 1
Equipment and Instrumentation 2
Procedures 2
Results 3
Discussion 4
Conclusions 4
References 6

APPENDICES

APPENDIX A - Mean Scores for Each Subtest of the ANAM A-1
APPENDIX B - Percentage from Baseline for Postdive Assessment B-1
APPENDIX C - ANOVA Results for Each ANAM Subtest C-1

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INTRODUCTION

This technical report partially addresses issues associated with Naval Sea Systems Command (NAVSEA) Task 99-005c and Annex A of Navy Experimental Diving Unit (NEDU) Test Protocol 99-22 (TP99-22).[1]

Operational performance and safety are important in any challenging environment. Work in extremely warm water is an unexplored subject that this study addresses. The data gathered during this series of dives provide guidelines for early identification of potential changes in diver health and for investigations of divers' reports of subtle changes in their cognitive functioning.

The purposes of the study were to assess the neuropsychological safety of exposure to a warm water environment, to ensure proper documentation of the divers' neuropsychological state before and after warm water exposure, and to identify any residual effects from exposure to warm water.

METHODS

GENERAL

A sample of 20 diver subjects was exposed to various temperature and work modes to determine the effects of warm water on cognitive abilities. All pre-dive and post-dive assessments were made in the physiological laboratory at NEDU. All diving evolutions occurred in the NEDU test pool.

EXPERIMENTAL DESIGN AND ANALYSIS

Each subject participated in various phases of the study, but not at all work or temperature levels. For analytic purposes, the measurements were treated as independent observations, even though some subjects participated in multiple phases. The small sample sizes and phase memberships do not permit data to be analyzed as dependent observations across temperature and work modes.

The data were generated by the Automated Neuropsychological Assessment Metrics (ANAM) software.[2,3] The variables considered were mean reaction time (MRT), the average response latency in milliseconds for the duration of each test; accuracy (acc), the percentage of correct responses for each test; and throughput (thruput), a measure of the number of correct responses made each minute and used as an index of mental efficiency.

The data were compiled using the Statview feature of ANAM[3] and transferred to Microsoft® Excel for storage and manipulation. The data were then transferred to SPSS 10.0 for the analyses, which consisted of mixed Analyses of Variances (ANOVA) using the General Linear Model (GLM) Repeated Measure. Of the three factors, the first — the within-subject factor — consisted of two levels: the pre- and postdive assessment. The other two factors were

between-subject factors: temperature (five levels) and work mode (two levels). Tukey's post hoc test was used for all significant main effects of temperature.

EQUIPMENT AND INSTRUMENTATION

Only the equipment involved with ANAM will be discussed here. For more discussion of the other equipment used, please refer to NEDU TP99-22.[1]

The equipment consisted of Micron Transport Trek II laptop computers (Micron PC, 900 East Karcher Road, Nampa, ID) with 366 Pentium processors, a standard mouse and the ANAM software.

The ANAM software is a standard clinical subset of the Office of the Military Performance Assessment Technology (OMPAT) Tester's Workbench (TWB).[2,3]
The ANAM was developed from selected elements of the Unified Tri-service Committee Performance Assessment Battery (UTCPAB)[4] and the Walter Reed Performance Assessment Battery.[5] ANAM's development and composition are discussed in detail elsewhere.[2,3]

The tests in the ANAM battery were selected for assessing sustained concentration and attention; mental flexibility; spatial processing; cognitive processing efficiency; mood; arousal/fatigue level; and short-term, long-term, and working memory. Specifically, the ANAM battery that was used included the following subtests:[3]

- Demographics form
- Stanford Sleepiness Scale (measures alertness/fatigue level)
- Mood Scale 2-R (measures current mood level or state)
- Simple reaction time (measures basic psychomotor speed)
- Code substitution (measures visual scanning and learning through letter/symbol comparison)
- Code substitution with long and short delay (measures intermediate and delayed recall)
- Running memory continuous performance task (CPT) (measures working memory and executive functions)
- Mathematical processing task (measures computational speed and working memory)
- Matching to sample (measures delayed recall/longer-term memory)

Demographics, sleepiness and mood are not discussed here.

PROCEDURES

The study assessed responses of 20 subjects, 19 male and 1 female, each participating in various aspects of the study. Exposures to five water temperatures were investigated: 78, 94,

96.5, 99, and 101.5 °F. For all temperature levels except 78 degrees, investigations were made working and resting. In the work mode, each subject pedaled a bicycle either four hours or until he or she voluntarily aborted the trial. In rest mode, subjects were immersed for a total of eight hours or until they voluntarily aborted the trial. The specifics of the equipment used in the diving phase are covered in NEDU TP99-22.[1]

Each subject took the neuropsychological assessment at least four times during a workup period to ensure a stable rate of performance before the study began. Then each subject took the assessment before each dive and within one hour of surfacing from the dive, provided that the subject did not abort the dive for displaying any of the medical criteria discussed in NEDU TP99-22.[1] If the subject did abort under these circumstances, he or she took the postdive portion of the assessment as soon as the other physiological measures and his or her condition allowed.

RESULTS

Appendix A lists means and standard errors of the mean (SEM) for each measure, while Appendix B shows the changes from baseline for each subject. For mean reaction time, performance decrements are increases from baseline, while for accuracy and throughput, decrements are decreases from baseline.

Appendix C lists the results of the repeated measures analysis of variance (ANOVA) for each variable. Significant effects of warm water diving are listed below:

Code substitution
Code substitution accuracy was lower after diving than before ($p = 0.018$), with no influence of water temperature or work mode. Code substitution MRT and throughput were not different after the dive from that before (no main effect).

Code substitution with short delay
Code substitution with short delay showed reduced accuracy ($p < 0.001$) and a marginally shortened MRT ($p = 0.05$) after dives, without influence of temperature or work mode.

Code substitution with long delay
No significant differences in MRT or throughput were caused by the dives. Diving reduced accuracy ($p < 0.001$) independently of temperature or work mode.

Simple reaction time
Diving did not affect simple reaction time measures.

Continuous performance task
Continuous performance accuracy and throughput both decreased after diving (accuracy $p = 0.001$, throughput $p = 0.03$). Neither accuracy nor throughput was affected by temperature or work mode.

Matching to sample
Matching to sample throughput decreased with diving ($p = 0.015$) without significant effects of temperature or work mode. MRT increased marginally with diving ($p = 0.051$), with a statistically significant temperature interaction
($p = 0.042$). The greatest reaction time increase was seen in 96.5 °F water.

Mathematical processing
No decrement in performance was associated with the dives.

DISCUSSION

Some changes in cognitive effects after diving were detected by ANAM. However, water temperature interacted significantly with diving only for matching to sample MRT. Unfortunately, due to our small sample size, our ability to discriminate other differences was impaired. The power of the tests is tabulated with the other statistics in Appendix C.

In the absence of a significant effect of the dives or of interaction with the dive exposure ("within factor 'A'"), effects ascribed to temperature or workload are caused by something other than the warm water diving. These effects have not been delineated.

Code substitution with short delay is a measure of short-term memory, and code substitution with long delay is a measure of long-term memory. They are generally correlated. The continuous performance task is a measure of vigilance or attention. Long and short-term memory functions and vigilance were reduced after the dives, but the decrements may have been caused by fatigue; temperature and work had no measurable influence.

Matching to sample is a test of pattern recognition and attention. Diving reduced accuracy, but water temperature did not affect the decrement. However, water temperature was related in some way to reaction time. The pattern is not clear because of the small sample sizes at higher water temperatures.

Mathematical processing was not indicative of diving effects. One possible reason is that it was the last test in the battery, administered after subjects were no longer motivated to perform. Possibly, single iterations of each subtest might produce better results.

CONCLUSIONS

Some cognitive changes were associated with warm water diving, but need to be further defined. Resolution of effects could be improved if larger sample sizes were available to increase statistical power. For this study comparisons to non-diving control groups were not possible because of other operational commitments, but they might also help differentiate between effects of fatigue and those of warm water diving.

The cognitive assessment of divers who must abort for medical or physiological reasons must be delayed until the diver's physical condition is stable. This prevents the detection of possibly important cognitive deficits that could accompany the physical distress. If one could use a single-run version of ANAM during the dive, one might measure cognitive function as the physical condition of the diver begins to deteriorate. Mid-point measurements could provide greater benefit, and single-run ANAM assessments require only a few minutes.

ANAM was unable to show a link between warm water exposure and neuropsychological risk. Pattern recognition speed may be reduced after warm water exposure, but this result must be regarded as preliminary because of the low number of subjects and the marginal probabilities. However, several divers had dramatic cognitive changes (confusion, hallucinations, etc...) immediately upon surfacing from the warm water dives. Tests of these divers were delayed until the divers were medically stable. Tests of all other divers were delayed at least 10 minutes and up to one hour after surfacing. These recovery periods may explain why ANAM was unable to detect the significant cognitive impairment seen immediately postdive at the warmer temperatures.

Finally, other methods should be used to assess factors of diver motivation and to assess decision making. In special warfare, the combatant must reach the operation area, make decisions based on a sound perception of available information, act on these decisions, and return safely. Preserving cognitive functioning is vital for completing missions and countermeasures must be developed to address any decrements in such capabilities, not only to ensure mission success, but also to ensure the safety of the individual.

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Appendix A

Mean Scores for Each Subtest of the Automated Neuropsychological Assessment Metrics (ANAM)

Code Substitution
Mean Scores

TEMP	WORK		premrt milliseconds	postmrt milliseconds	preacc percent	postacc percent	prethpt corr/min	postthpt corr/min
78	work	N	15	15	15	15	15	15
		Mean	1210	1479	95	95	50	42
		SEM	86	116	2	1	4	3
94	rest	N	18	18	18	18	18	18
		Mean	1169	1386	97	93	53	44
		SEM	84	100	1	2	3	3
	work	N	18	18	18	18	18	18
		Mean	1216	1372	94	94	51	44
		SEM	91	90	3	1	4	3
96.5	rest	N	8	7	8	7	8	7
		Mean	1078	1321	91	97	60	45
		SEM	155	86	6	1	9	3
	work	N	15	15	15	15	15	15
		Mean	1181	1236	93	89	50	51
		SEM	89	132	2	4	3	5
99	rest	N	2	2	2	2	2	2
		Mean	1418	808	96	88	45	70
		SEM	433	259	2	13	14	14
	work	N	12	12	12	12	12	12
		Mean	1354	1341	95	89	45	45
		SEM	117	135	1	3	3	3
101.5	rest	N	5	5	5	5	5	5
		Mean	868	857	83	81	59	75
		SEM	96	225	9	7	5	20
	work	N	12	12	12	12	12	12
		Mean	1388	1256	94	90	44	56
		SEM	122	182	1	3	4	9

Legend:

TEMP-Temperature of water
WORK - Working rate
work - Riding bicycle
rest - No work
premrt - Mean reaction time baseline
postmrt - Mean reaction time postdive
preacc - Accuracy baseline
postacc - Accuracy postdive
prethpt - Thruput score baseline
postthpt - Thruput score postdive
corr/min - Number of correct responses per minute (a purported measure of mental efficiency)

Code Substitution - Short Delay
Mean Scores

TEMP	WORK		premrt milliseconds	postmrt milliseconds	preacc percent	postacc percent	prethpt corr/min	postthpt corr/min
78	work	N	15	15	15	15	15	15
		Mean	1201	1206	91	86	47	45
		SEM	72	81	3	5	3	5
94	rest	N	18	18	18	18	18	18
		Mean	1370	1212	92	78	46	48
		SEM	132	98	2	4	4	8
	work	N	18	18	18	18	18	18
		Mean	1259	1102	93	80	48	50
		SEM	81	98	2	5	3	9
96.5	rest	N	8	7	8	7	8	7
		Mean	1143	1218	94	92	52	48
		SEM	124	121	3	5	4	6
	work	N	15	15	15	15	15	15
		Mean	1244	965	96	72	49	55
		SEM	83	89	2	5	4	11
99	rest	N	2	2	2	2	2	2
		Mean	1123	778	75	75	49	56
		SEM	302	26	25	25	24	19
	work	N	12	12	12	12	12	12
		Mean	1299	1144	91	86	47	51
		SEM	128	133	3	4	4	4
101.5	rest	N	5	5	5	5	5	5
		Mean	874	896	85	70	81	60
		SEM	289	193	10	11	19	16
	work	N	12	12	12	12	12	12
		Mean	1433	1191	92	81	43	50
		SEM	172	148	3	6	5	6

Legend:

TEMP-Temperature of water
WORK - Working rate
work - Riding bicycle
rest - No work
premrt - Mean reaction time baseline
postmrt - Mean reaction time postdive
preacc - Accuracy baseline
postacc - Accuracy postdive
prethpt - Thruput score baseline
postthpt - Thruput score postdive
corr/min - Number of correct responses per minute (a purported measure of mental efficiency)

Code Substitution - Long Delay Means

TEMP	WORK		premrt milliseconds	postmrt milliseconds	preacc percent	postacc percent	prethpt corr/min	postthpt corr/min
78	work	N	15	15	15	15	15	15
		Mean	1264	1141	94	82	47	45
		SEM	72	57	2	5	3	5
94	rest	N	18	18	18	18	18	18
		Mean	1313	1222	93	75	45	48
		SEM	82	122	2	5	3	8
	work	N	18	18	18	18	18	18
		Mean	1253	1125	92	79	47	50
		SEM	77	108	3	5	3	9
96.5	rest	N	8	7	8	7	8	7
		Mean	1186	1317	93	85	48	48
		SEM	66	187	4	5	3	6
	work	N	15	15	15	15	15	15
		Mean	1198	1001	88	69	47	55
		SEM	98	118	4	5	4	11
99	rest	N	2	2	2	2	2	2
		Mean	777	1031	70	75	55	56
		SEM	119	119	24	25	8	19
	work	N	12	12	12	12	12	12
		Mean	1153	1205	85	81	47	51
		SEM	69	140	5	6	4	4
101.5	rest	N	5	4	5	4	5	5
		Mean	840	613	78	60	67	60
		SEM	241	227	12	9	12	16
	work	N	12	12	12	12	12	12
		Mean	1268	1156	85	75	44	50
		SEM	117	158	4	7	4	6

Legend:

TEMP-Temperature of water
WORK - Working rate
work - Riding bicycle
rest - No work
premrt - Mean reaction time baseline
postmrt - Mean reaction time postdive
preacc - Accuracy baseline
postacc - Accuracy postdive
prethpt - Thruput score baseline
postthpt - Thruput score postdive
corr/min - Number of correct responses per minute (a Purported measure of mental efficiency)

Simple Reaction Time
Mean Scores

TEMP	WORK		premrt milliseconds	postmrt milliseconds	prethpt corr/min	postthpt corr/min
78	work	N	16	16	16	16
		Mean	319	325	195	196
		SEM	19	23	8	11
94	rest	N	19	19	19	19
		Mean	305	346	203	188
		SEM	14	27	8	11
	work	N	18	18	18	18
		Mean	304	339	208	190
		SEM	19	27	11	10
96.5	rest	N	8	8	8	8
		Mean	294	282	207	216
		SEM	13	13	9	9
	work	N	15	15	15	15
		Mean	306	353	201	180
		SEM	14	25	8	11
99	rest	N	2	1	2	1
		Mean	349	291	176	206
		SEM	50	.	25	.
	work	N	12	12	12	12
		Mean	300	370	203	178
		SEM	11	39	7	14
101.5	rest	N	5	4	5	4
		Mean	336	369	184	179
		SEM	27	56	16	36
	work	N	12	13	12	13
		Mean	322	349	196	183
		SEM	23	26	12	13

Legend:

TEMP-Temperature of water
WORK - Working rate
work - Riding bicycle
rest - No work
premrt - Mean reaction time baseline
postmrt - Mean reaction time postdive
preacc - Accuracy baseline
postacc - Accuracy postdive
prethpt - Thruput score baseline
postthpt - Thruput score postdive
corr/min - Number of correct responses per minute (a purported measure of mental efficiency)

Continuous Performance Task
Mean Scores

TEMP	WORK		premrt	postmrt	preacc	postacc	prethpt	postthpt
			milliseconds	milliseconds	percent	percent	corr/min	corr/min
78	work	N	16	16	16	16	16	16
		Mean	567	571	90	87	100	97
		SEM	26	29	3	4	6	6
94	rest	N	19	19	19	19	19	19
		Mean	592	581	90	88	97	96
		SEM	29	30	3	3	6	6
	work	N	18	18	18	18	18	18
		Mean	568	559	91	85	101	94
		SEM	31	24	3	5	6	6
96.5	rest	N	8	8	8	8	8	8
		Mean	502	516	91	87	111	104
		SEM	30	30	4	5	5	6
	work	N	15	15	15	15	15	15
		Mean	566	541	92	80	102	92
		SEM	29	34	4	5	6	6
99	rest	N	2	1	2	1	2	1
		Mean	406	477	84	97	126	123
		SEM	44	.	16	.	8	.
	work	N	12	12	12	12	12	12
		Mean	558	576	90	89	101	97
		SEM	33	32	4	4	7	8
101.5	rest	N	5	4	5	4	5	4
		Mean	521	475	87	68	101	87
		SEM	37	29	4	12	8	14
	work	N	12	13	12	13	12	13
		Mean	548	551	91	82	105	95
		SEM	32	27	4	5	8	8

Legend:

TEMP-Temperature of water
WORK - Working rate
work - Riding bicycle
rest - No work
premrt - Mean reaction time baseline
postmrt - Mean reaction time postdive
preacc - Accuracy baseline
postacc - Accuracy postdive
prethpt - Thruput score baseline
postthpt - Thruput score postdive
corr/min - Number of correct responses per minute (a purported measure of mental efficiency)

Matching to Sample
Mean Scores

TEMP	WORK		premrt milliseconds	postmrt milliseconds	preacc percent	postacc percent	prethpt corr/min	postthpt corr/min
78	work	N	16	16	16	16	16	16
		Mean	483	1336	41	89	1278	42
		SEM	66	83	3	2	77	3
94	rest	N	19	19	19	19	19	19
		Mean	562	1382	41	91	1314	41
		SEM	62	76	2	2	75	3
	work	N	18	18	18	18	18	18
		Mean	468	1471	44	87	1231	38
		SEM	80	89	3	3	83	3
96.5	rest	N	8	8	8	8	8	8
		Mean	435	1364	45	94	1128	43
		SEM	109	129	5	4	88	5
	work	N	15	15	15	15	15	15
		Mean	442	1462	44	85	1185	38
		SEM	58	118	3	4	62	3
99	rest	N	2	1	2	1	2	1
		Mean	378	1481	36	100	1511	41
		SEM	136	.	6	.	177	.
	work	N	12	12	12	12	12	12
		Mean	404	1325	43	86	1242	40
		SEM	52	108	3	5	92	3
101.5	rest	N	5	4	5	4	5	4
		Mean	361	1184	50	74	1002	37
		SEM	48	124	6	12	106	9
	work	N	12	13	12	13	12	13
		Mean	457	1367	43	85	1180	39
		SEM	82	88	3	5	73	3

Legend:

TEMP-Temperature of water
WORK - Working rate
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postmrt - Mean reaction time postdive
preacc - Accuracy baseline
postacc - Accuracy postdive
prethpt - Thruput score baseline
postthpt - Thruput score postdive
corr/min - Number of correct responses per minute (a purported measure of mental efficiency)

Mathematical Computation
Mean Scores

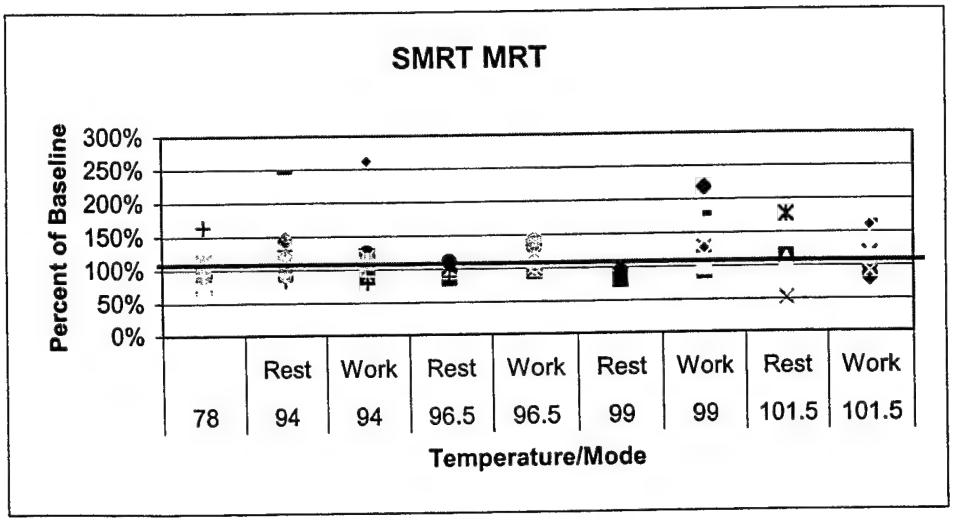
TEMP	WORK		premrt milliseconds	postmrt milliseconds	preacc percent	postacc percent	prethpt corr/min	postthpt corr/min
78	work	N	16	16	16	16	16	16
		Mean	1860	1795	90	91	32	33
		SEM	135	130	2	2	2	3
94	rest	N	19	19	19	19	19	19
		Mean	1965	1842	92	89	30	32
		SEM	122	151	2	3	2	3
	work	N	18	18	18	18	18	18
		Mean	1774	1752	94	87	33	31
		SEM	115	158	1	4	2	2
96.5	rest	N	8	8	8	8	8	8
		Mean	1919	1780	88	89	32	33
		SEM	268	236	6	5	4	4
	work	N	15	15	15	15	15	15
		Mean	1649	1521	87	82	33	38
		SEM	104	160	4	5	2	5
99	rest	N	2	1	2	1	2	1
		Mean	1043	1539	83	95	44	36
		SEM	282	.	13	.	3	.
	work	N	12	12	12	12	12	12
		Mean	1736	2035	92	88	35	29
		SEM	171	191	3	3	3	3
101.5	rest	N	5	4	5	4	5	4
		Mean	1260	1221	74	73	39	46
		SEM	228	398	10	12	7	21
	work	N	12	13	12	13	12	13
		Mean	1811	1764	93	80	33	30
		SEM	152	183	3	7	2	3

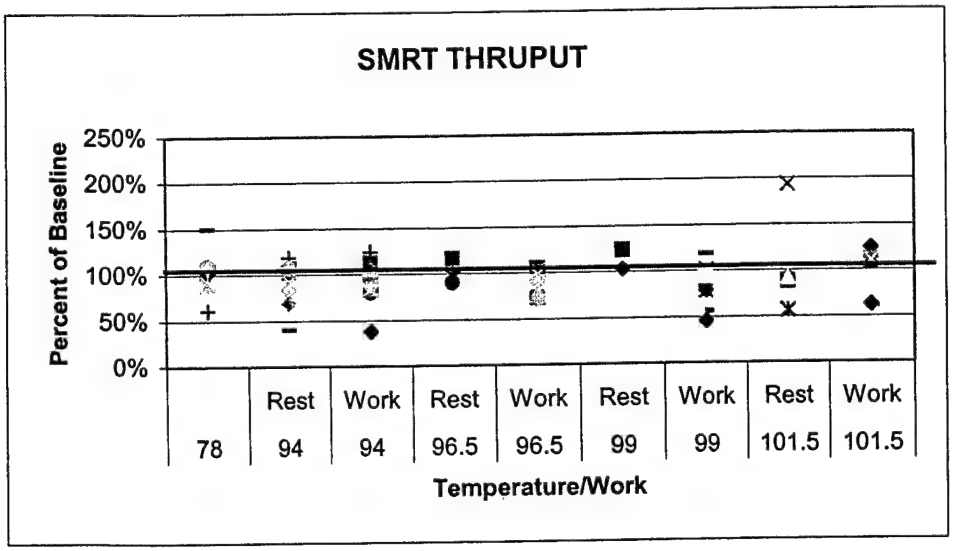
Legend:

TEMP-Temperature of water
WORK - Working rate
work - Riding bicycle
rest - No work
premrt - Mean reaction time baseline
postmrt - Mean reaction time postdive
preacc - Accuracy baseline
postacc - Accuracy postdive
prethpt - Thruput score baseline
postthpt - Thruput score postdive
corr/min - Number of correct responses per minute (a purported measure of mental efficiency)

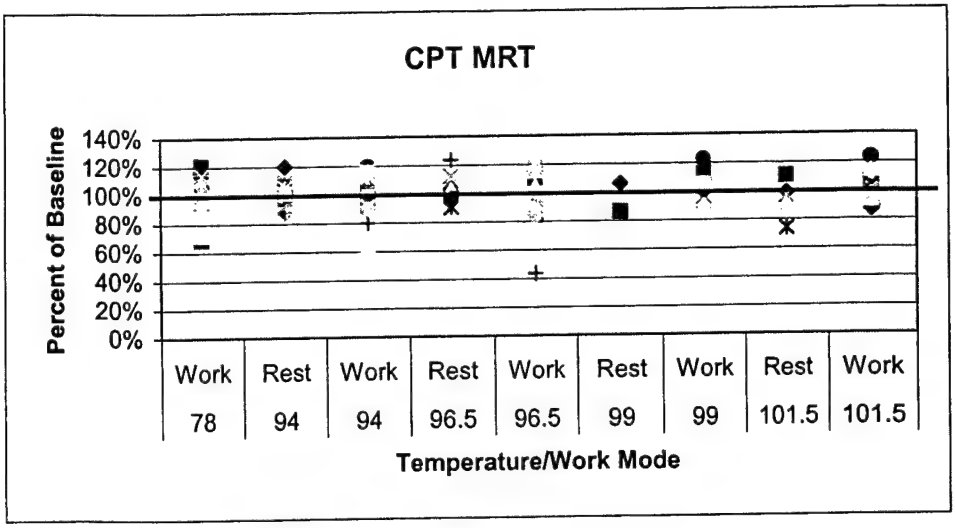
Appendix B

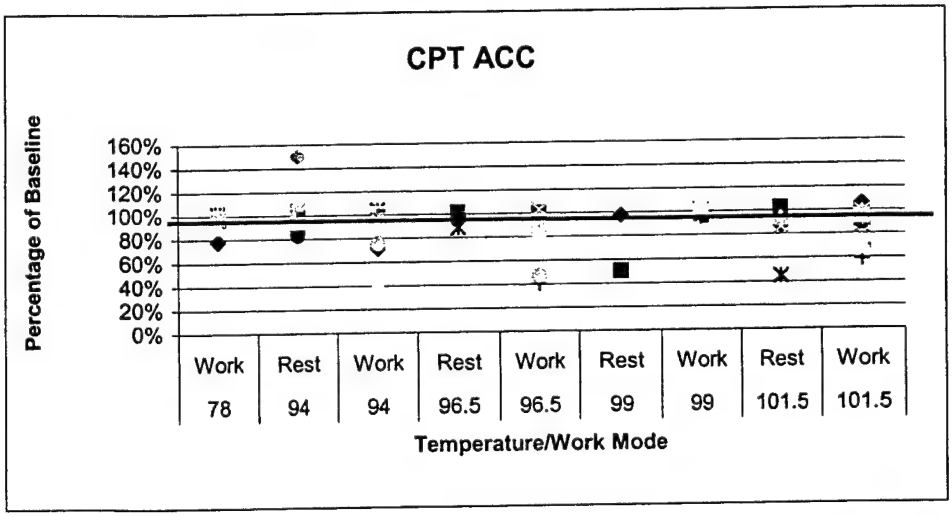
Percentage from Baseline for Postdive Assessment

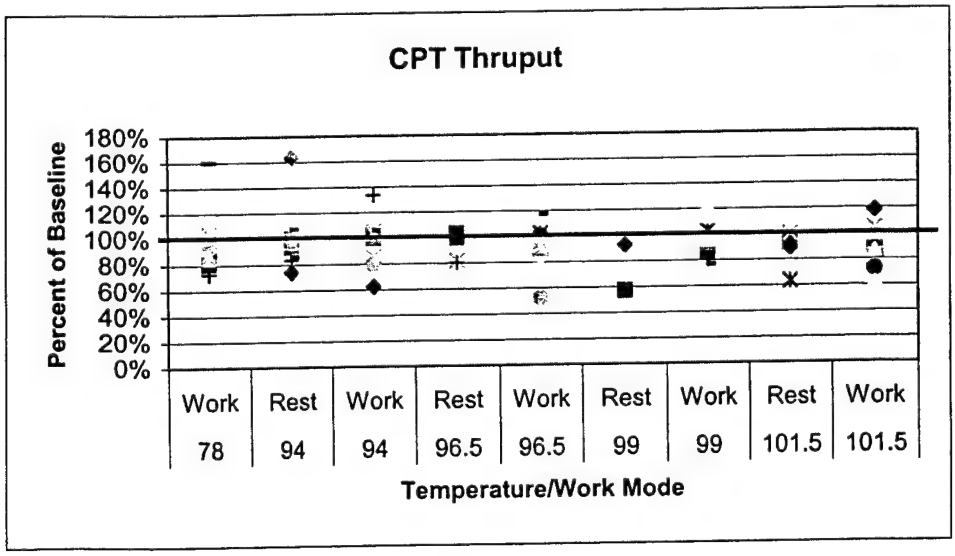


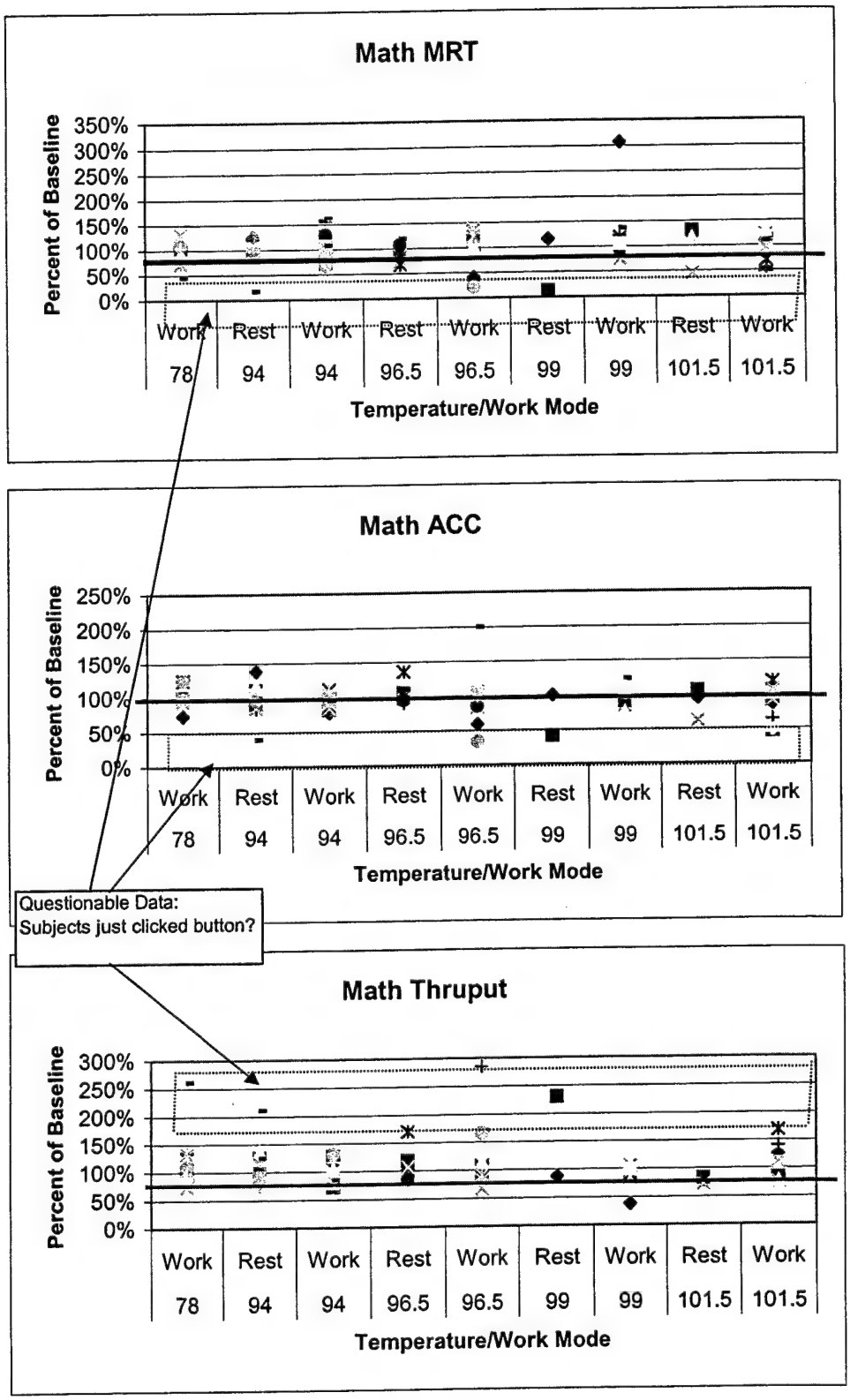


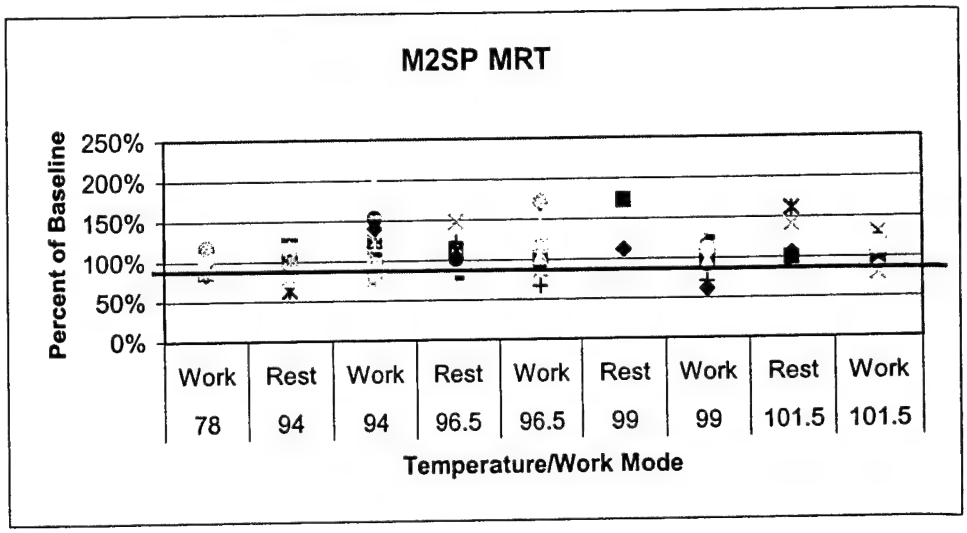
Legend: (Use for all charts)
Symbols represent the individual subjects
SMRT - Simple reaction time
MRT - Mean reaction time
ACC - Accuracy
Thruput - Throughput
CPT - Continuous performance task
Math - Mathematical processing
M2SP - Matching to sample
Codesub - Code substitution
Codesub MI - Code substitution short delay
Codesub MD - Code substitution long delay

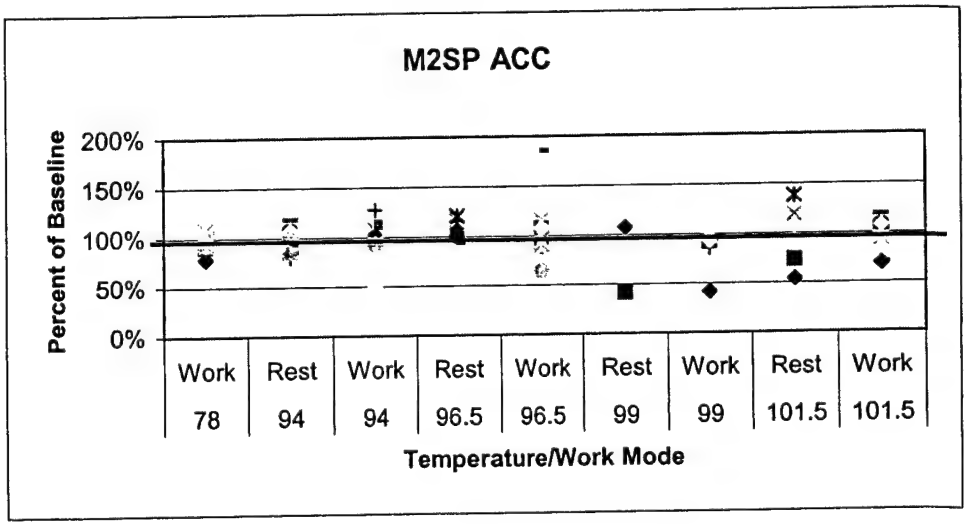

CPT MRT
Percent of Baseline
140%
120%
100%
80%
60%
40%
20%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode

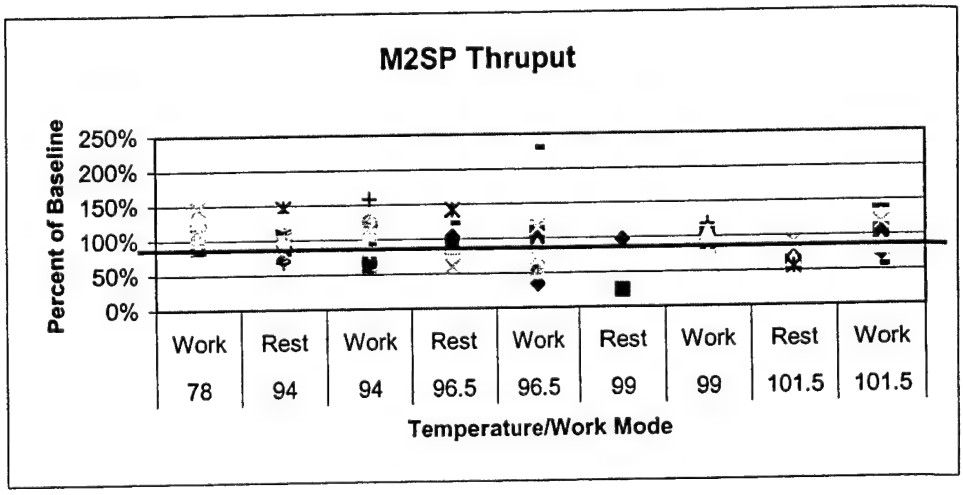

CPT ACC
Percentage of Baseline
160%
140%
120%
100%
80%
60%
40%
20%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode

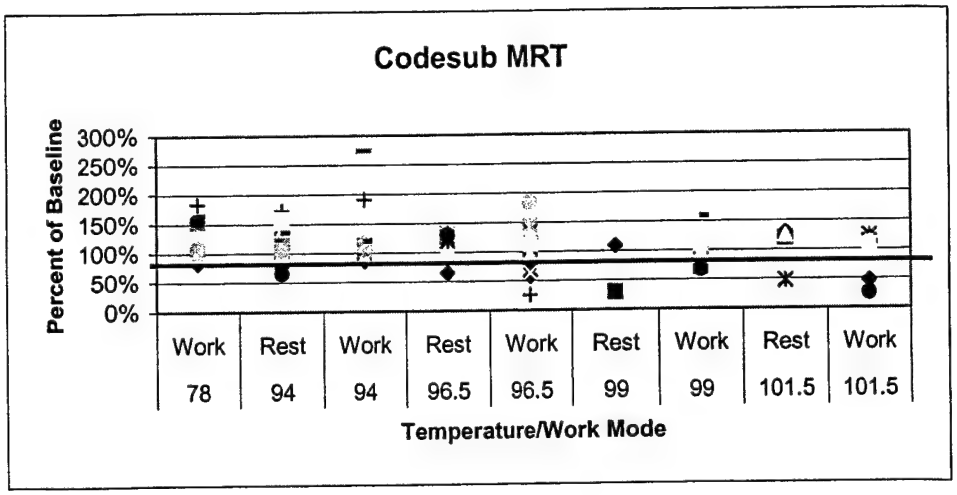

CPT Thruput
Percent of Baseline
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode

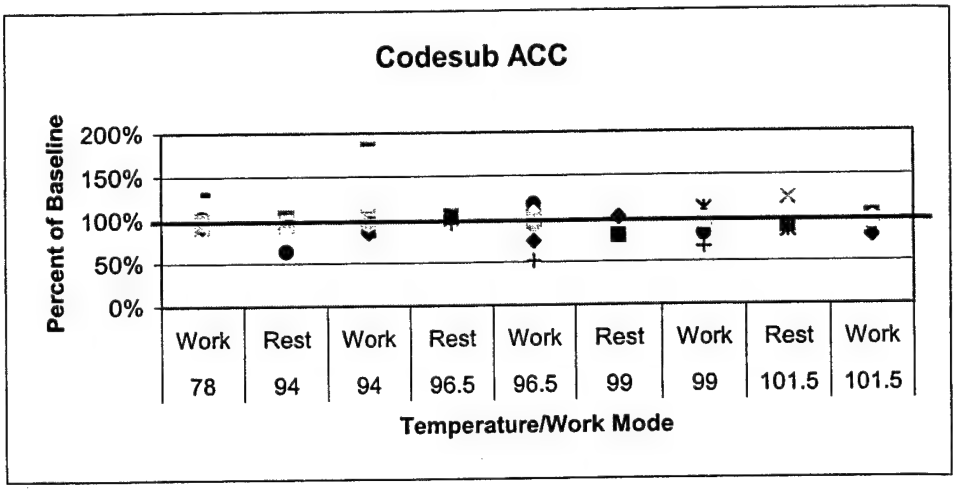

Math MRT
Percent of Baseline
350%
300%
250%
200%
150%
100%
50%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode
Math ACC
Percent of Baseline
250%
200%
150%
100%
50%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode
Questionable Data:
Subjects just clicked button?
Math Thruput
Percent of Baseline
300%
250%
200%
150%
100%
50%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode

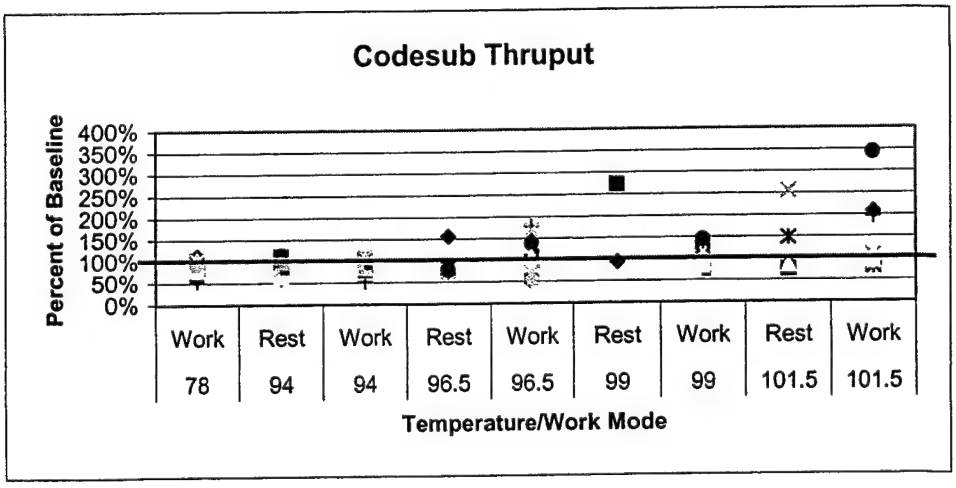

M2SP MRT
Percent of Baseline
250%
200%
150%
100%
50%
0%
Work 78
Rest 94
Work 94
Rest 96.5
Work 96.5
Rest 99
Work 99
Rest 101.5
Work 101.5
Temperature/Work Mode

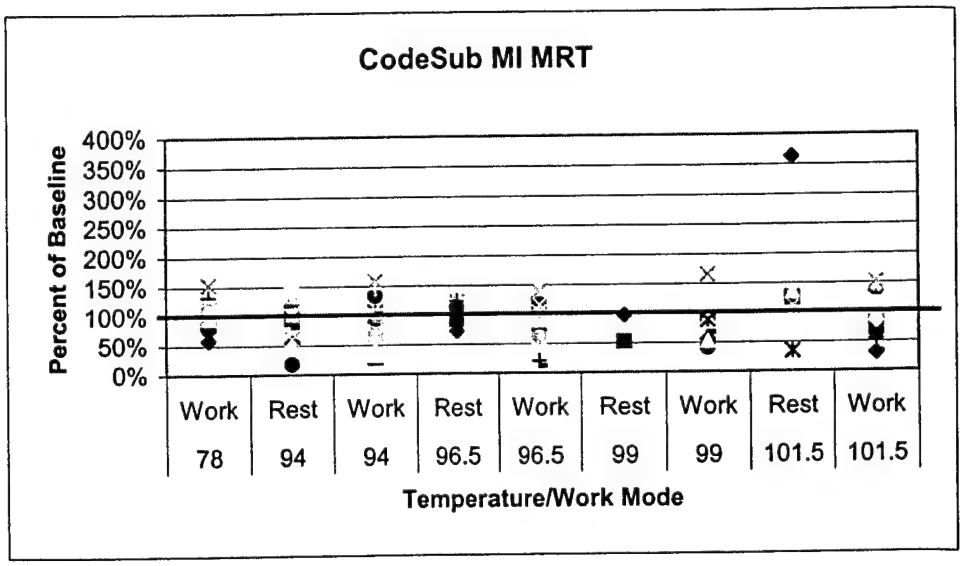

M2SP ACC
Percent of Baseline
200%
150%
100%
50%
0%
Work 78
Rest 94
Work 94
Rest 96.5
Work 96.5
Rest 99
Work 99
Rest 101.5
Work 101.5
Temperature/Work Mode

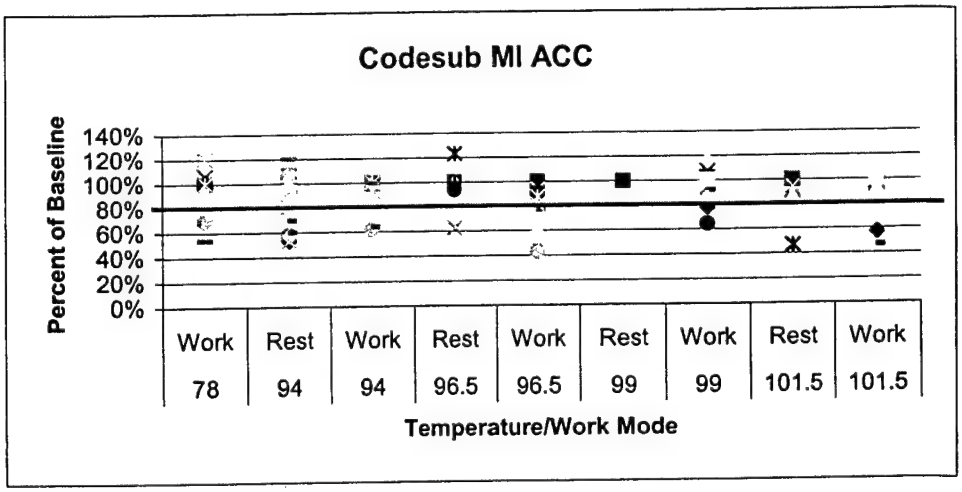

M2SP Thruput
Percent of Baseline
250%
200%
150%
100%
50%
0%
Work 78
Rest 94
Work 94
Rest 96.5
Work 96.5
Rest 99
Work 99
Rest 101.5
Work 101.5
Temperature/Work Mode

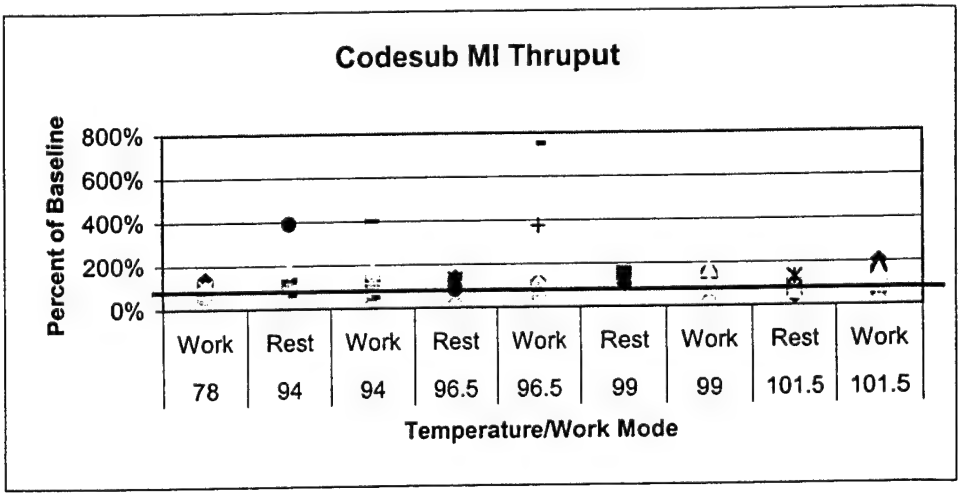

Codesub MRT
Percent of Baseline
300%
250%
200%
150%
100%
50%
0%
Work 78
Rest 94
Work 94
Rest 96.5
Work 96.5
Rest 99
Work 99
Rest 101.5
Work 101.5
Temperature/Work Mode

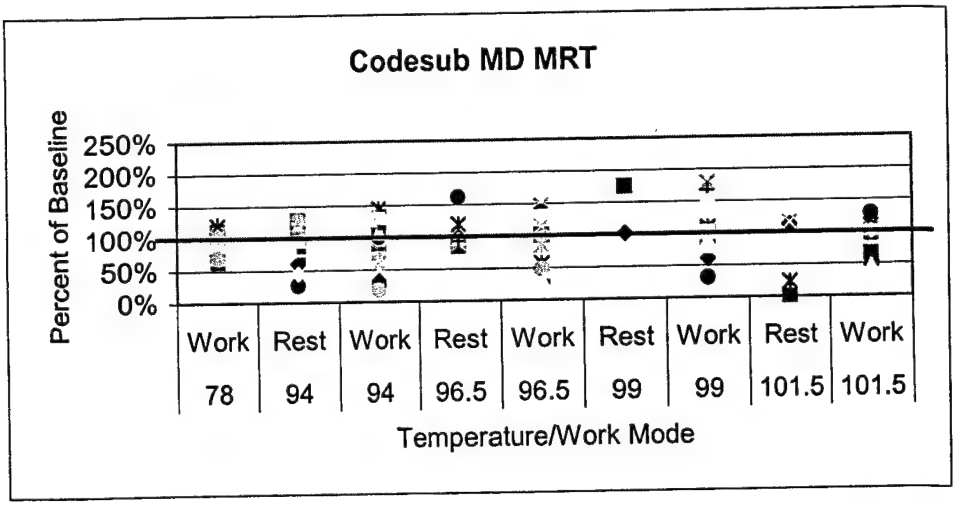

Codesub ACC
Percent of Baseline
200%
150%
100%
50%
0%
Work 78
Rest 94
Work 94
Rest 96.5
Work 96.5
Rest 99
Work 99
Rest 101.5
Work 101.5
Temperature/Work Mode

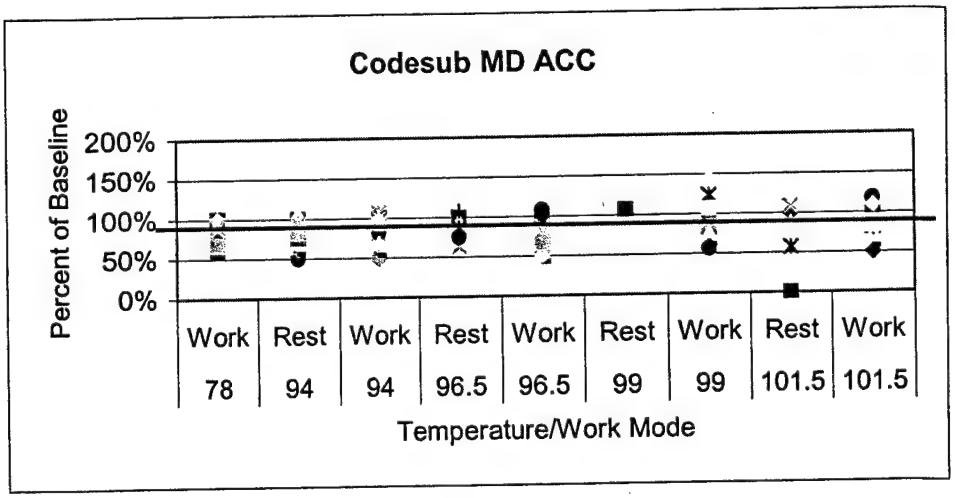

Codesub Thruput
Percent of Baseline
400%
350%
300%
250%
200%
150%
100%
50%
0%
Work 78
Rest 94
Work 94
Rest 96.5
Work 96.5
Rest 99
Work 99
Rest 101.5
Work 101.5
Temperature/Work Mode

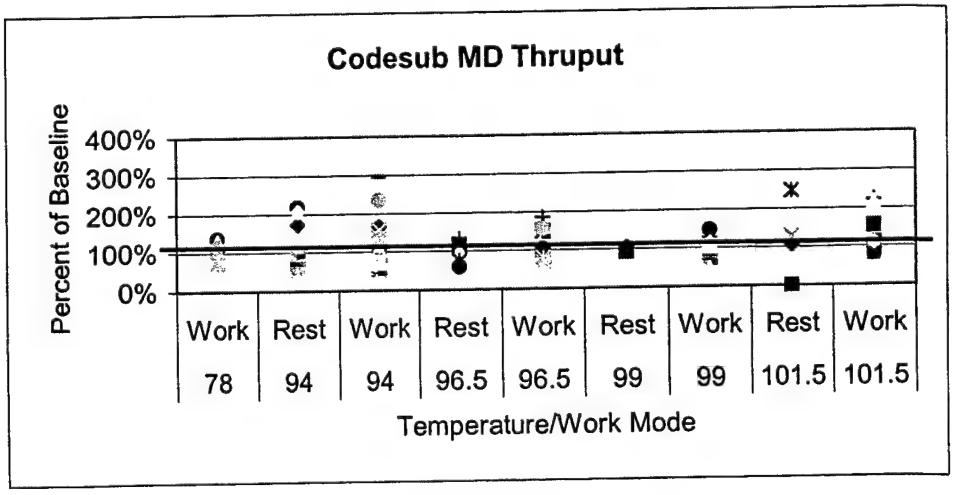

CodeSub MI MRT
Percent of Baseline
400%
350%
300%
250%
200%
150%
100%
50%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode


Codesub MI ACC
Percent of Baseline
140%
120%
100%
80%
60%
40%
20%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode


Codesub MI Thruput
Percent of Baseline
800%
600%
400%
200%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode


Codesub MD MRT
Percent of Baseline
250%
200%
150%
100%
50%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode


Codesub MD ACC
Percent of Baseline
200%
150%
100%
50%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode


Codesub MD Thruput
Percent of Baseline
400%
300%
200%
100%
0%
Work Rest Work Rest Work Rest Work Rest Work
78 94 94 96.5 96.5 99 99 101.5 101.5
Temperature/Work Mode

Appendix C

ANOVA Results for Each ANAM Subtest

Code Substitution
Mean Reaction Time

	Source	SS	df	MS	F	p	power
Within							
	A	6212.214	1	6212.214	0.089	0.766	0.069
	A X B	1222422.565	4	305605.641	4.377	**0.003**	0.923
	A X C	46555.061	1	46555.061	0.667	0.416	0.124
	A X B X C	359850.372	3	119950.124	1.718	0.169	0.43
	Error	6632890.335	95	69819			
Between							
	B	805740.007	4	201435.002	0.719	0.581	0.225
	C	745795.096	1	745795.096	2.663	0.106	0.365
	B X C	1296202.406	3	432067.469	1.543	0.208	0.395
	Error	26604292.78	95	280045			

Code Substitution
Accuracy

	Source	SS	df	MS	F	p	power
Within							
	A	270.301	1	270.301	5.839	**0.018**	0.667
	A X B	154.749	4	38.687	0.836	0.506	0.258
	A X C	0.159	1	0.195	0.003	0.953	0.05
	A X B X C	98.931	3	32.977	0.712	0.547	0.196
	Error	4397.951	95	46.294			
Between							
	B	1305.797	4	326.449	2.718	**0.034**	0.733
	C	15.746	1	15.746	0.131	0.718	0.065
	B X C	1047.801	3	349.267	2.908	**0.039**	0.676
	Error	11411.269	95	120.119			

Code Substitution
Thruput

	Source	SS	df	MS	F	p	power
Within							
	A	163.69	1	163.69	1.002	0.319	0.168
	A X B	3604.053	4	901.013	5.518	**0.000**	0.972
	A X C	180.907	1	180.907	1.108	0.295	0.181
	A X B X C	745.595	3	248.532	1.522	0.214	0.39
	Error	15513.509	95	163.3			
Between							
	B	2399.469	4	599.867	1.515	0.204	0.453
	C	1411.078	1	1411.078	3.565	0.062	0.464
	B X C	1884.357	3	628.119	1.587	0.198	0.406
	Error	37606.258	95	395.855			

Legend: A - Within main effect (pre to postdive); B- Temperature; C- Work mode

Code Substitution Short Delay
Mean Reaction Time

	Source	SS	df	MS	F	p	power
Within							
	A	482391.975	1	482391.975	3.931	**0.05**	0.501
	A X B	324284.966	4	81071.242	0.661	0.621	0.208
	A X C	64720.867	1	64720.867	0.527	0.469	0.111
	A X B X C	276121.314	3	92040.438	0.75	0.525	0.205
	Error	11658253.63	95	122718.459			
Between							
	B	560532.218	4	140133.054	0.594	0.668	0.19
	C	409134.513	1	409134.513	1.734	0.191	0.256
	B X C	1815875.052	3	605291.684	2.566	0.059	0.615
	Error	22410838.68	95	235903.565			

Code Substitution Short Delay
Accuracy

	Source	SS	df	MS	F	p	power
Within							
	A	2661.994	1	2661.994	18.364	**0.000**	0.989
	A X B	801.559	4	200.39	1.382	0.246	0.416
	A X C	167.797	1	167.797	1.158	0.285	0.187
	A X B X C	838.015	3	279.338	1.927	0.13	0.484
	Error	13771.136	95	144.959			
Between							
	B	1110.336	4	277.584	0.828	0.511	0.256
	C	347.571	1	347.571	1.036	0.311	0.172
	B X C	2075.957	3	691.986	2.063	0.11	0.514
	Error	31862.082	95	335.39			

Code Substitution Short Delay
Thruput

	Source	SS	df	MS	F	p	power
Within							
	A	1.801	1	1.801	0.004	0.952	0.05
	A X B	829.725	4	207.431	0.419	0.795	0.144
	A X C	408.863	1	408.863	0.826	0.366	0.147
	A X B X C	1059.511	3	353.17	0.714	0.546	0.197
	Error	47022.557	95	494.974			
Between							
	B	2344.752	4	586.188	0.782	0.54	0.242
	C	828.286	1	828.286	1.105	0.296	0.18
	B X C	3865.986	3	1288.662	1.719	0.168	0.436
	Error	71229.99	95	749.789			

Legend: A - Within main effect (pre to postdive); B- Temperature; C- Work mode

Code Substitution Long Delay
Mean Reaction Time

	Source	SS	df	MS	F	p	power
Within							
	A	62944.727	1	62944.727	0.523	0.471	0.11
	A X B	252292.24	4	63073.06	0.524	0.718	0.171
	A X C	77366.729	1	77366.729	0.643	0.425	0.125
	A X B X C	175159.428	3	58386.476	0.486	0.693	0.145
	Error	11304305.83	94	120258.573			
Between							
	B	1477647.554	4	369411.889	1.807	0.134	0.532
	C	441179.28	1	441179.28	2.158	0.145	0.307
	B X C	2088961.003	3	696320.334	3.406	**0.021**	0.752
	Error	19217545.99	94	204441.979			

Code Substitution Long Delay
Accuracy

	Source	SS	df	MS	F	p	power
Within							
	A	3099.806	1	3099.806	22.605	**0.000**	0.997
	A X B	786.078	4	196.52	1.433	0.229	0.43
	A X C	39.268	1	39.268	0.286	0.594	0.083
	A X B X C	287.001	3	95.667	0.698	0.556	0.193
	Error	12889.978	94	137.127			
Between							
	B	3500.46	4	875.115	1.883	0.12	0.551
	C	322.558	1	322.558	0.694	0.407	0.131
	B X C	2947.361	3	982.454	2.114	0.104	0.524
	Error	43691.089	94	464.799			

Code Substitution Long Delay
Thruput

	Source	SS	df	MS	F	p	power
Within							
	A	9.846	1	9.846	0.045	0.833	0.055
	A X B	405.362	4	101.34	0.46	0.765	0.154
	A X C	30.854	1	30.854	0.14	0.709	0.066
	A X B X C	431.952	3	143.984	0.654	0.583	0.183
	Error	20699.792	94	220.211			
Between							
	B	3428.434	4	857.109	2.347	0.06	0.66
	C	1815.009	1	1815.009	4.971	**0.028**	0.597
	B X C	5855.597	3	1951.866	5.345	**0.002**	0.924
	Error	34323.532	94	365.144			

Legend: A - Within main effect (pre to postdive); B- Temperature; C- Work mode

Simple Reaction Time
Mean Reaction Time

	Source	SS	df	MS	F	p	power
Within							
	A	10352.735	1	10352.735	2.343	0.129	0.329
	A X B	13533.873	4	3383.468	0.766	0.550	0.238
	A X C	6475.956	1	6475.956	1.466	0.229	0.224
	A X B X C	8433.418	3	2811.139	0.636	0.593	0.179
	Error	424155.803	96	4418.2			
Between							
	B	27885.029	4	6971.257	0.637	0.637	0.202
	C	3884.401	1	3884.401	0.355	0.553	0.091
	B X C	21272.924	3	7090.975	0.648	0.586	0.182
	Error	1049799.283	96	10935.409			

Simple Reaction Time
Thruput

	Source	SS	df	MS	F	p	power
Within							
	A	962.143	1	962.143	1.271	0.262	0.200
	A X B	3783.244	4	945.811	1.249	0.295	0.378
	A X C	2030.771	1	2030.771	2.682	0.105	0.368
	A X B X C	1377.401	3	459.134	0.606	0.612	0.172
	Error	72683.928	96	757.124			
Between							
	B	6259.416	4	1564.854	0.624	0.646	0.198
	C	499.892	1	499.892	0.199	0.656	0.073
	B X C	5328.981	3	1776.327	0.708	0.549	0.196
	Error	240743.817	96	2507.748			

Legend: A - Within main effect (pre to postdive); B- Temperature; C- Work mode

Continuous Performance Task
Mean Reaction Time

	Source	SS	df	MS	F	p	power
Within							
	A	271.771	1	271.771	0.101	0.752	0.061
	A X B	3563.821	4	890.955	0.33	0.857	0.122
	A X C	224.699	1	224.699	0.083	0.774	0.059
	A X B X C	12272.743	3	4090.914	1.516	0.215	0.389
	Error	259064.757	96	2698.591			
Between							
	B	78577.651	4	19644.413	0.843	0.502	0.26
	C	34905.685	1	34905.685	1.497	0.224	0.228
	B X C	57297.015	3	19099.005	0.819	0.486	0.221
	Error	2238305.139	96	23315.679			

Continuous Performance Task
Accuracy

	Source	SS	df	MS	F	p	power
Within							
	A	768.059	1	768.059	12.348	**0.001**	0.936
	A X B	457.746	4	114.437	1.84	0.127	0.54
	A X C	0.15	1	0.15	0.002	0.961	0.05
	A X B X C	304.337	3	101.446	1.631	0.187	0.416
	Error	5971.098	96	62.199			
Between							
	B	1169.96	4	292.49	0.703	0.592	0.22
	C	23.299	1	23.299	0.056	0.813	0.056
	B X C	833.178	3	277.726	0.668	0.574	0.186
	Error	39940.091	96	416.043			

Continuous Performance Task
Thruput

	Source	SS	df	MS	F	p	power
Within							
	A	877.036	1	877.036	9.191	**0.003**	0.851
	A X B	368.89	4	92.223	0.966	0.430	0.296
	A X C	16.591	1	16.591	0.174	0.678	0.07
	A X B X C	82.804	3	27.601	0.289	0.833	0.104
	Error	9160.305	96	95.42			
Between							
	B	2617.158	4	654.289	0.574	0.682	0.185
	C	1120.974	1	1120.974	0.983	0.324	0.166
	B X C	2887.429	3	962.476	0.844	0.473	0.227
	Error	109452.91	96	1140.134			

Legend: A - Within main effect (pre to postdive); B- Temperature; C- Work mode

Matching To Sample
Mean Reaction Time

	Source	SS	df	MS	F	p	power
Within							
	A	146086.532	1	146086.532	3.905	0.051	0.499
	A X B	385285.908	4	96321.477	2.574	**0.042**	0.706
	A X C	1113.422	1	1113.422	0.03	0.863	0.053
	A X B X C	204819.126	3	68273.042	1.825	0.148	0.461
	Error	3591805.127	96	37414.637			
Between							
	B	903633.042	4	225908.26	1.036	0.393	0.316
	C	89249.868	1	89249.868	0.409	0.524	0.097
	B X C	511342.33	3	170447.443	0.782	0.507	0.213
	Error	20926077.82	96	217979.977			

Matching To Sample
Accuracy

	Source	SS	df	MS	F	p	power
Within							
	A	53.821	1	53.821	0.637	0.427	0.124
	A X B	180.52	4	45.13	0.534	0.711	0.174
	A X C	143.35	1	143.35	1.697	0.196	0.252
	A X B X C	202.947	3	67.649	0.801	0.497	0.217
	Error	8111.469	96	84.494			
Between							
	B	1480.005	4	370.001	1.56	0.191	0.466
	C	6.583	1	6.583	0.028	0.868	0.053
	B X C	1356.172	3	452.057	1.905	0.134	0.479
	Error	22775.575	96	237.246			

Matching To Sample
Thruput

	Source	SS	df	MS	F	p	power
Within							
	A	252.821	1	252.821	6.183	**0.015**	0.692
	A X B	376.023	4	94.006	2.299	0.064	0.65
	A X C	0.547	1	0.547	0.013	0.908	0.052
	A X B X C	315.538	3	105.179	2.572	0.059	0.617
	Error	3925.273	96	40.888			
Between							
	B	119.156	4	29.789	0.115	0.977	0.073
	C	42.687	1	42.687	0.164	0.686	0.069
	B X C	117.702	3	39.234	0.151	0.929	0.077
	Error	24912.91	96	259.509			

Legend: A - Within main effect (pre to postdive); B- Temperature; C- Work mode

Mathematical Processing
Mean Reaction Time

	Source	SS	df	MS	F	p	power
Within							
	A	7.903E-03	1	7.903E-03	0.000	1	0.050
	A X B	340425.687	4	85106.422	0.606	0.659	0.193
	A X C	14174.431	1	14174.431	0.101	0.751	0.061
	A X B X C	16520.277	3	5506.759	0.039	0.990	0.057
	Error	13484618.57	96	140464.777			
Between							
	B	1926653.878	4	481663.47	0.863	0.489	0.266
	C	490795.202	1	490795.202	0.879	0.351	0.153
	B X C	3615029.853	3	1205009.95	2.159	0.098	0.534
	Error	53574662.93	96	558069.405			

Mathematical Processing
Accuracy

	Source	SS	df	MS	F	p	power
Within							
	A	106.087	1	106.087	0.684	0.410	0.130
	A X B	385.513	4	96.378	0.621	0.648	0.198
	A X C	183.051	1	183.051	1.18	0.280	0.189
	A X B X C	86.222	3	28.741	0.185	0.906	0.083
	Error	14887.857	96	155.082			
Between							
	B	2215.827	4	553.957	2.178	0.077	0.623
	C	48.586	1	48.586	0.191	0.663	0.072
	B X C	1726.965	3	575.655	2.264	0.086	0.556
	Error	24413.099	96	254.303			

Mathematical Processing
Thruput

	Source	SS	df	MS	F	p	power
Within							
	A	0.826	1	0.826	0.011	0.918	0.051
	A X B	194.908	4	48.727	0.63	0.642	0.2
	A X C	23.845	1	23.845	0.308	0.580	0.085
	A X B X C	225.475	3	75.158	0.971	0.410	0.258
	Error	7427.963	96	77.375			
Between							
	B	614.959	4	153.74	0.692	0.600	0.217
	C	221.352	1	221.352	0.996	0.321	0.167
	B X C	884.143	3	294.714	1.326	0.271	0.343
	Error	21339.68	96	222.288			

Legend: A - Within main effect (pre to postdive); B- Temperature; C- Work mode